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Date: August 25, 2000
Docket No.: 3430-0131P

Assistant Commissioner for Patents
Box PATENT APPLICATION
Washington, D.C. 20231

Sir:

As authorized by the inventor(s), transmitted herewith for filing
is a patent application applied for on behalf of the inventor(s)
according to the provisions of 37 CFR 1.41(c).

Inventor(s): HWANG, Kwang-Jo

For: METHOD OF PATTERNING A METAL LAYER IN A SEMICONDUCTOR
DEVICE

Enclosed are:

- A specification consisting of 14 pages
- 04 sheet(s) of Formal drawings
- Certified copy of Priority Document(s)
- Executed Declaration in accordance with 37 CFR 1.64 will follow
- A verified statement to establish small entity status under 37 CFR 1.9 and 37 CFR 1.27
- Preliminary Amendment
- Information Sheet
- Information Disclosure Statement, PTO-1449 with reference(s)

Other _____

The filing fee has been calculated as shown below:

| FOR | NO. FILED | NO. EXTRA | LARGE ENTITY | | SMALL ENTITY | |
|---------------------------------------|-----------|-----------|--------------|----------|--------------|----------|
| | | | RATE | Fee | RATE | Fee |
| BASIC FEE | ***** | ***** | **** | | **** | |
| | ***** | ***** | **** | \$690.00 | **** | \$345.00 |
| | ***** | ***** | **** | | **** | |
| TOTAL CLAIMS | 29 - 20 = | 9 | x18 = \$ | 162.00 | or x 9 = \$ | 0.00 |
| INDEPENDENT | 3 - 3 = | 0 | x78 = \$ | 0.00 | or x 39 = \$ | 0.00 |
| MULTIPLE DEPENDENT CLAIM PRESENTED | <u>no</u> | | +260 = \$ | 0.00 | or +130 = \$ | 0.00 |
| | | | | | | |
| | | | TOTAL \$ | 852.00 | TOTAL \$ | 0.00 |

- The application transmitted herewith is filed in accordance with 37 CFR 1.41(c). The undersigned has been authorized by the inventor(s) to file the present application. The original duly executed patent application together with the surcharge will be forwarded in due course.
- A check in the amount of \$ 852.00 to cover the filing fee and recording fee (if applicable) is enclosed.
- The Government Filing Fee will be paid at the time of completion of the filing requirement.
- Please charge Deposit Account No. 02-2448 in the amount of \$. A triplicate copy of this transmittal form is enclosed.
- Send Correspondence to: BIRCH, STEWART, KOLASCH & BIRCH, LLP
P. O. Box 747
Falls Church, Virginia 22040-0747

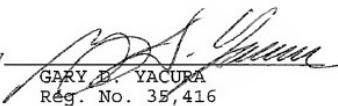
— No fee is enclosed.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. 1.16 or under 37 C.F.R. 1.17; particularly, extension of time fees.

Respectfully submitted,

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IN THE U.S. PATENT AND TRADEMARK OFFICE

INFORMATION SHEET

Applicant: HWANG, Kwang-Jo

Application No.:

Filed: August 25, 2000

For: METHOD OF PATTERNING A METAL LAYER IN A SEMICONDUCTOR
DEVICE

Priority Claimed:

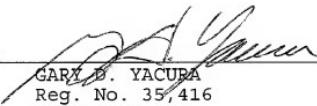
| COUNTRY | DATE | NUMBER |
|-------------------|----------|------------|
| REPUBLIC OF KOREA | 08/26/99 | 1999-35739 |

Send Correspondence to: BIRCH, STEWART, KOLASCH & BIRCH, LLP
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(703) 205-8000The above information is submitted to advise the USPTO of all
relevant facts in connection with the present application. A timely
executed Declaration in accordance with 37 CFR 1.64 will follow.

Respectfully submitted,

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**Method of Patterning a Metal Layer in a Semiconductor
Device**

Cross Reference

This application claims the benefit under 35 U.S.C. § 119 of Korean Patent Application No. 1999-35739, filed on August 26, 1999, the entirety of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to manufacturing metal patterns in semiconductor devices, and more particularly, to a method of manufacturing such metal patterns. This method is applicable to the manufacture of electrodes in liquid crystal display (LCD) devices.

Description of Related Art

A typical LCD device includes first and second transparent substrates with a liquid crystal layer interposed therebetween. The first substrate has a thin film transistor (TFT) as a switching element and a pixel electrode disposed thereon, and the second substrate has a color filter disposed thereon. The pixel electrode serves to apply a voltage to the liquid crystal layer, and the color filter serves to transmit only certain colors of light passing through the liquid crystal.

As shown in Fig. 1, the typical LCD device includes a substrate 1 and a gate electrode 2 formed on the substrate 1. A gate insulating layer 3 covers the whole

surface of the substrate 1 and the gate electrode 2. A semiconductor layer 4 is formed over the gate electrode 2. Source and drain electrodes 5 and 6 are formed spaced apart from each other on the gate insulating layer 3 and each overlapping a part of the semiconductor layer 4. A passivation layer 7 is formed on the whole surface of the substrate 1, as well as the source and drain electrodes 5 and 6 and a portion of the semiconductor layer 4. A pixel electrode 9 is formed on the passivation layer 7 and contacts the drain electrode 6 through a contact hole 8 in the passivation layer 7.

Figs. 2 and 3 illustrate a conventional method of forming the area "II" shown circled in the LCD device of Fig. 1. In order to form the pixel electrode 9, first a metal layer 14 is deposited on the passivation layer 7. The metal layer 14 is made of a transparent conductive material such as indium tin oxide (ITO) or indium zinc oxide (IZO). Subsequently, photoresist is applied on the metal layer 14 and is patterned to form a photoresist pattern 16 shown in Fig. 2. Then, the metal layer 14 is conventionally etched to form the pixel electrode 9 using the photoresist pattern 16 as a mask. Finally, the photoresist pattern 16 is removed.

Conventional techniques for etching the metal layer 14 have the following disadvantages. In case of wet etching techniques, an organic substance such as a photoresist remnant 16a shown in Fig. 3 may be left on the pixel electrode 9 and the passivation layer 7. This is due to heat generated during the photolithography process. Also, pin holes and cracks may develop in the metal layer 14 when wet etching. Further, the gate electrode 2 and the connecting gate line (not shown) may become open due to the wet etchant. Because wet etching causes the problems of low yields and line defects, dry etching techniques have also been conventionally used for etching.

In case of dry etching techniques, the etch rate is typically low, so that the

array substrate is subjected to radio frequency (RF) power for a long time. The photoresist pattern may be damaged by maintaining the array substrate at a high temperature. As a result, the photoresist pattern is not easy to remove, leading to a high defect rate. Further, if the RF power is increased to improve the etch rate, the temperature of the array substrate becomes greater, leading to the photoresist problem described above. For example, as illustrated in Fig. 4, the RF power curve 22 of 2000 watts causes the substrate temperature to increase at a greater rate than the RF power curve 20 of 1500 watts.

SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to a method of patterning a metal layer in a semiconductor device that substantially obviates one or more of the problems due to limitations and disadvantages of the related art.

In accordance with the purpose of the invention, as embodied and broadly described, in one aspect the invention includes a method of patterning a metal layer, including depositing a metal layer over a substrate; forming a mask on the metal layer, leaving a portion of the metal layer uncovered; exposing the uncovered portion of the metal layer to a first plasma to lower a binding force in the uncovered portion; and removing the uncovered portion of the metal layer with a second plasma to form a metal pattern.

In another aspect, the invention includes a method of manufacturing a pixel electrode in a liquid crystal display device, including depositing a metal layer on a passivation layer which partially covers a transistor; forming a photoresist pattern on the metal layer, leaving a portion of the metal layer uncovered; exposing the uncovered

portion of the metal layer to a first plasma to lower a binding force in the uncovered portion; and removing the uncovered portion of the metal layer with a second plasma to form a pixel electrode.

In still another aspect, the invention includes a method of manufacturing a liquid crystal display device, including forming a switching element on a substrate; forming a passivation layer over the substrate; depositing a metal layer on the passivation layer; forming a photoresist pattern on the metal layer, such that a portion of the metal layer is exposed; treating the exposed portion of the metal layer with a plasma using the photoresist pattern as a mask; and removing the treated portion of the metal layer to form a pixel electrode.

Using the method of manufacturing according to the present invention, semiconductor devices (e.g., LCD devices) having advantageously high yields may be obtained.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

The accompanying drawings are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate one embodiment of the invention and together with the description serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following descriptions taken in conjunction with

the accompanying drawings.

Fig. 1 is a cross sectional view illustrating a conventional LCD device.

Figs. 2 and 3 are enlarged cross sectional views illustrating a method of manufacturing a pixel electrode in a portion "II" of the conventional LCD device in Fig. 1.

Fig. 4 is an exemplary graph illustrating the temperature of the substrate in relation to a dry etching processing time.

Fig. 5 is a cross sectional view illustrating an LCD device manufactured according to a preferred embodiment of the present invention.

Figs. 6A and 6B are enlarged cross sectional views illustrating a method of manufacturing a pixel electrode in a portion "VI" of the LCD device in Fig. 5.

Fig. 7 is a graph illustrating an etch rate of an amount of plasma gas according to the preferred embodiment of the present invention, and an etch rate according to the conventional art for comparison.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Reference will now be made in detail to a preferred embodiment of the present invention, example of which is illustrated in the accompanying drawings.

Fig. 5 is a cross sectional view illustrating an LCD device manufactured according to a preferred embodiment of the present invention. As shown in Fig. 5, the inventive LCD device includes a substrate 31 and a gate electrode 32 formed on the substrate 31. A gate insulating layer 33 covers the whole surface of the substrate 31 and the gate electrode 32. A semiconductor layer 34 is formed over the gate electrode 32. Source and drain electrodes 35 and 36 are formed spaced apart from each other on the

gate insulating layer 33 and each overlapping a part of the semiconductor layer 34. A passivation layer 37 is formed on the whole surface of the substrate 31, as well as the source and drain electrodes 35 and 36 and a portion of the semiconductor layer 34. A pixel electrode 39 is formed on the passivation layer 37 and contacts the drain electrode 36 through a contact hole 38 in the passivation layer 37. There is no organic material remaining on the pixel electrode 39 or on the adjacent passivation layer 37 from the device's manufacturing process.

Figs. 6A and 6B illustrate a method of manufacturing a pixel electrode in the area "VI" shown circled in the LCD device of Fig. 5. As shown in Fig 6A, first a metal layer 44 is deposited on the passivation layer 37. The metal layer 44 is made of indium tin oxide (ITO) and the passivation layer is made of a silicon nitride (SiNx) film. In an alternate embodiment, the metal layer 44 may be made of indium zinc oxide (IZO). Subsequently a photoresist is applied on the metal layer 44 and patterned to form a photoresist pattern 36.

Then, the exposed surface of the metal layer 44 is plasma-treated by the reactive gas such as H₂ plasma gas using the photoresist pattern 36 as a mask. Also, a non-reactive gas such as Ar or N₂ plasma gas can be used for the plasma treatment. When using the H₂ plasma gas, the composition of the metal layer 44 is varied so that the binding force of the metal layer 44 becomes depressed. In particular, the H₂ gas reacts with oxygen in the ITO layer 44, so that H₂O is formed and only indium metal remains. The binding force of the remaining indium metal is lower, and the metal is correspondingly easier to etch. When using the non-reactive gas, such as the Ar or N₂ plasma gas, the binding force of the surface of the metal layer 44 becomes depressed physically. In particular, Ar or N₂ ions physically strike the surface of the metal layer

44, thereby breaking chemical bonds and lowering the overall binding force of the metal layer. This lower binding force of the metal layer 44 causes the high etch rate in subsequent processing.

Subsequently, as shown in Fig. 6B, the metal layer 44 is plasma-etched to form the pixel electrode 39 using hydrogen bromide (HBr) plasma gas. Other plasma gasses, such as those mentioned with respect to Fig. 7, may be used to etch the metal layer 44. The present invention has an etch rate twice as high as the conventional art under similar conditions where the same RF power is applied.

Fig. 7 is a graph illustrating the etch rates according to the preferred embodiment of the present invention, and according to the conventional art for comparison purposes. The horizontal axis indicates the amount of the plasma gas composition whose unit is a standard cubic per centimeter (SCCM), and the vertical axis indicates the etch rate of the metal layer ($\text{\AA}/\text{min}$). A curve 50 denotes the etch rate of the metal layer 44 according to the preferred embodiment of the present invention, and a curve 52 denotes the etch rate of the metal layer 44 according to the conventional art.

As shown in Fig. 7, when etching the metal layer 44 using HBr plasma gas of 200 SCCM, the etch rate according to the present invention is about twice as high as that according to the conventional art. When etching the metal layer 44 using a compound of the HBr plasma gas and Cl_2 plasma gas whose mixing ratio is 200:50, the present invention has an etch rate about 100 $\text{\AA}/\text{min}$ higher than the conventional art method. When etching the metal layer 44 using a compound of the HBr plasma gas and CH_4 plasma gas whose mixing ratio is 200:50, the etch rate according to the present invention is higher than the conventional art, though the improvement in the etch rate is smaller than with other plasma compounds.

As described herein, using the method of manufacturing metal patterns according to the preferred embodiment of the present invention, semiconductor devices (e.g., LCD devices) having high manufacturing yields can be obtained.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that the foregoing and other changes in form and details may be made therein without departing from the spirit and scope of the invention. For example, although the method of patterning a metal layer according to the invention has been primarily described with respect to a pixel electrode in an LCD device, this method is also generally applicable to forming metal patterns of other geometries and uses in semiconductor devices. The invention described above is therefore not intended to be limited to LCD devices, but rather encompasses all metal patterns so formed with easier removal of the metal layer and faster processing time. Thus, it is intended that the present invention cover the modifications and variations of the this invention provided that they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A method of manufacturing a liquid crystal display device, comprising:
forming a switching element on a substrate;
forming a passivation layer over the substrate;
depositing a metal layer on the passivation layer;

forming a photoresist pattern on the metal layer, such that a portion of the metal layer is exposed;

treating the exposed portion of the metal layer with a plasma using the photoresist pattern as a mask; and

removing the treated portion of the metal layer to form a pixel electrode.

2. The method of claim 1, wherein the switching element is a thin film transistor.

3. The method of claim 1, wherein the step of treating the exposed portion of the metal layer includes,

using a reactive gas to lower a binding force in the exposed portion.

4. The method of claim 3, wherein the reactive gas includes H₂ plasma gas.

5. The method of claim 1, wherein the step of treating the exposed portion of the metal layer includes,

using a non-reactive gas to lower a binding force in the exposed portion.

6. The method of claim 5, wherein the non-reactive gas includes Ar or N₂ plasma gas.

7. The method of claim 1, wherein the step of etching the metal layer involves a dry-etching technique.

8. The method of claim 7, wherein the step of etching the metal layer includes,

etching the metal layer with HBr plasma gas.

9. The method of claim 7, wherein the step of etching the metal layer includes,

etching the metal layer with a composition of HBr plasma gas and Cl₂ plasma gas.

10. The method of claim 7, wherein the step of etching the metal layer includes,

etching the metal layer with a composition of HBr plasma gas and CH₄ plasma gas.

11. The method of claim 1, wherein the metal layer includes one of indium tin oxide (ITO) and indium zinc oxide (IZO).

12. A method of manufacturing a pixel electrode in a liquid crystal display device, comprising:

depositing a metal layer on a passivation layer which partially covers a transistor;

forming a photoresist pattern on the metal layer, leaving a portion of the metal layer uncovered;

exposing the uncovered portion of the metal layer to a first plasma to lower a binding force in the uncovered portion; and

removing the uncovered portion of the metal layer with a second plasma to form a pixel electrode.

13. The method of claim 12, wherein the first plasma is a reactive gas.

14. The method of claim 13, wherein the reactive gas includes H₂ plasma gas.

15. The method of claim 12, wherein the first plasma is a non-reactive gas.

16. The method of claim 15, wherein the non-reactive gas includes Ar or N₂ plasma gas.

17. The method of claim 12, wherein the second plasma includes HBr plasma gas.

18. The method of claim 12, wherein the second plasma includes a composition of HBr plasma gas and Cl₂ plasma gas.

19. The method of claim 12, wherein the second plasma includes a composition of HBr plasma gas and CH₄ plasma gas.

20. The method of claim 12, wherein the metal layer includes one of indium tin oxide (ITO) and indium zinc oxide (IZO).

21. The method of claim 12, further comprising:
removing the photoresist pattern from the pixel electrode.

22. A method of patterning a metal layer, comprising:
depositing a metal layer over a substrate;
forming a mask on the metal layer, leaving a portion of the metal layer uncovered;

exposing the uncovered portion of the metal layer to a first plasma to lower a binding force in the uncovered portion; and
removing the uncovered portion of the metal layer with a second plasma to form a metal pattern.

23. The method of claim 22, wherein the first plasma includes H₂ plasma gas.

24. The method of claim 22, wherein the first plasma includes Ar or N₂ plasma gas.

25. The method of claim 22, wherein the second plasma includes HBr plasma gas.

26. The method of claim 22, wherein the second plasma includes a composition of HBr plasma gas and Cl₂ plasma gas.

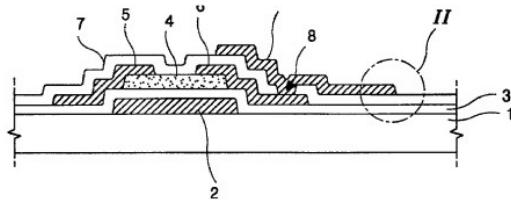
27. The method of claim 22, wherein the second plasma includes a composition of HBr plasma gas and CH₄ plasma gas.

28. The method of claim 22, wherein the metal layer includes one of indium tin oxide (ITO) and indium zinc oxide (IZO).

29. The method of claim 22, wherein the metal pattern includes a pixel electrode of a display device.

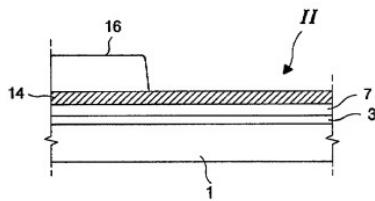
ABSTRACT OF THE DISCLOSURE

In a method of manufacturing a metal pattern, a metal layer is deposited on a passivation layer, and a photoresist pattern is then formed on the metal layer. Using the photoresist pattern as a mask, an exposed portion of the metal layer is treated with a plasma to lower a binding force in the metal. The metal layer is then etched to form a metal pattern. The method is applicable to the formation of pixel electrodes in LCD devices.



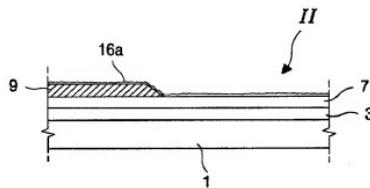
(RELATED ART)

FIG. 1



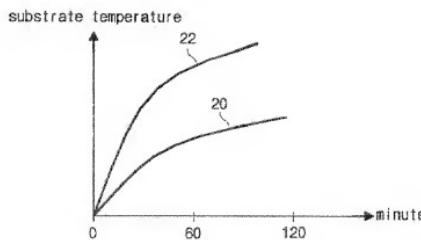
(RELATED ART)

FIG. 2



(RELATED ART)

FIG. 3



(RELATED ART)

FIG.4

INSTITUTE OF APPLIED PHYSICS

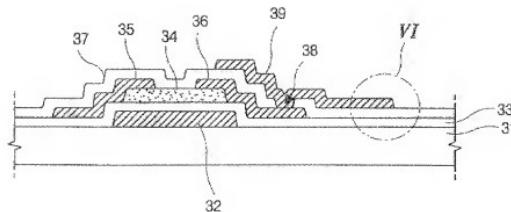


FIG.5

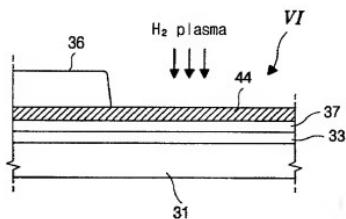


FIG. 6A

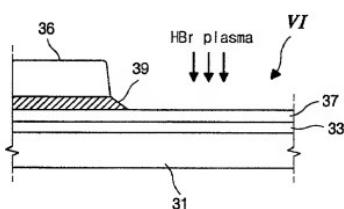


FIG. 6B

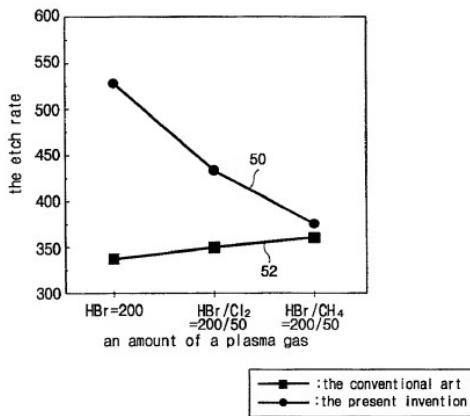


FIG.7